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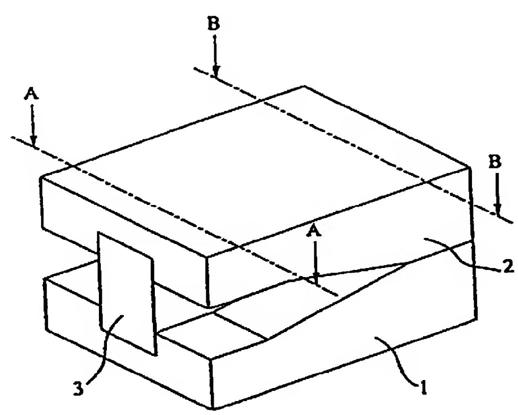
(54) Dielectric line converter, dielectric line unit, directional coupler, high-frequency circuit module, and transmitter-receiver

(57) Grooves are formed in the opposing surfaces of upper and lower conductor plates, and a dielectric stripline is arranged in the grooves. At the same time, the space between the conductor surfaces of a line conversion portion is made narrower than the space between the conductor surfaces of a first-kind dielectric line portion, and the impedance matching to a second-kind dielectric-loaded waveguide is arranged. Further, the line length of the line conversion portion is set to be an odd multiple of $\lambda g/4$.

FIG. 1A



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a line converter between dielectric lines of different kinds, and a directional coupler, dielectric line unit, high-frequency circuit module, and transmitter-receiver which use the line converter.

2. Description of the Related Art

[0002] In a circuit using dielectric lines, when lines of, for example, a waveguide, and so on, which are different in kind, are used in the input-output portion of the circuit or a part of the circuit, a line converter between the waveguide and dielectric line is required. For example, a line converter between a line made up of a waveguide in which a dielectric material is loaded(filled) (hereinafter, called DWG) and a non-radiative dielectric line in which a dielectric stripline is arranged between parallel conductor surfaces (hereinafter, called NRD guide) is shown in Japanese Unexamined Patent Publication No. 8-70209. In this line converter, the width of the dielectric stripline and the space of the wall surfaces (between the conductor surfaces) of the width direction are gradually widened over from the DWG to the NRD guide.

[0003] In the line converter between the above DWG and NRD guide, although the line converter has an advantage of low line conversion loss over a broad band, there was a problem that the line converter becomes large-sized as a whole because the line length of the line conversion portion is lengthened.

[0004] For example, as a circuit using dielectric lines, a directional coupler of a parallel-wire line type in which two dielectric striplines are arranged in parallel between two upper and lower conductor surfaces is used. An NRD guide can be used as a dielectric line, but the frequency bandwidth in which the characteristic values of power distribution ratio, and so on, are kept within fixed values is narrow. When a directional coupler of a waveguide type is composed of a DWG, although broad-band characteristics can be obtained, a line converter between the above DWG and NRD guide is required with a directional coupler of the DWG in order to realize the NRD guide as an input-output. As the result, the whole system becomes large-sized.

SUMMARY OF THE INVENTION

[0005] It is an object of the present invention to present a dielectric line converter which is able to keep a good line conversion characteristic and is made small-sized as a whole.

[0006] Further, it is another object of the present invention to present a directional coupler having wide-band characteristics and made up of small-sized dielectric lines.

[0007] It is further another object of the present invention to present a high-frequency circuit module and transmitter-receiver using a dielectric line unit or directional coupler of the above dielectric line converter.

[0008] In the present invention, a line converter comprises a first-kind dielectric line having upper and lower surfaces as a conductor surface of a dielectric stripline and spaces beside the dielectric stripline, a second-kind dielectric line having upper and lower surfaces and side surfaces as a conductor surface of a dielectric stripline, and a dielectric stripline connected to the dielectric striplines of the first-kind and second-kind dielectric line or being continuous with the dielectric striplines of the first-kind and second-kind dielectric line, wherein the space between the upper and lower conductor surfaces in the region except the dielectric striplines is made narrower than the space between the upper and lower conductor surfaces in the first-kind line, and wherein the space between the conductor surfaces in the second-kind dielectric line portion is made nearly zero.

[0009] Because of this construction, as the space between the upper and lower conductor surfaces sandwiching the dielectric stripline does not change abruptly over from the first-kind dielectric line to the second-kind dielectric line (dielectric-loaded waveguide), a line conversion takes place without deteriorating reflection characteristics, and as the line does not tend to be widened in its width direction it becomes easy to make the line converter small-sized in its width direction.

[0010] In the above construction, when the further the position is displaced from the first-kind dielectric line to the second-kind dielectric line, the narrower the space between the conductor surfaces except the region of the dielectric line, the reflection at the discontinuity portion is further suppressed.

[0011] Further, when the line length between the first-kind dielectric line and the second-kind dielectric line is made an odd multiple of a fourth of a wavelength on the line, the reflected waves at the two locations in which the space between the upper and lower conductor surfaces sandwiching the dielectric stripline changes are superposed in opposite phase, and consequently the reflected waves are canceled. Accordingly, the reflection characteristic is improved.

[0012] Further, In the present invention, a line converter comprises a first-kind dielectric line having upper and lower surfaces as a conductor surface of a dielectric stripline and spaces beside the dielectric stripline, a second-kind dielectric line having upper and lower surfaces and side surfaces as a conductor surface of a dielectric stripline, and a dielectric stripline connected to the dielectric striplines of the first-kind and second-kind dielectric line or being continuous with the dielectric striplines of the first-kind and second-kind dielectric line,

wherein the space from the dielectric stripline to the side conductor surface is made a fixed value which is narrower than the space from the dielectric stripline of the first-kind dielectric line to the side conductor surface.

[0013] Because of this construction, as the space between the upper and lower conductor surfaces sandwiching the dielectric stripline changes in a stepped way over from the first-kind dielectric line to the second-kind dielectric line (dielectric-loaded waveguide), the dimension of the line converter does not have to be long in its length direction. As the result, a short line converter in its length direction can be obtained.

[0014] In the above construction, when the line length between the first-kind dielectric line and the second-kind dielectric line is made an odd multiple of a fourth of a wavelength on the line, the reflected waves at the two locations in which the space between the upper and lower conductor surfaces sandwiching the dielectric stripline changes are superposed in opposite phase, and consequently the reflected waves are canceled. Accordingly, the reflection characteristic is improved.

[0015] When the line is composed of a dielectric line propagating a single LSM mode (hereinafter, called hyper-NRD guide) by making the space between the conductor surfaces of the above first-kind dielectric line narrower than the height of the dielectric stripline of the first-kind dielectric line, a dielectric line circuit having a dielectric line and dielectric-loaded waveguide which hardly causes any loss accompanying a mode conversion at a bend can be easily constructed.

[0016] Further, in the present invention, the above dielectric line converter constitutes a dielectric line unit. For example, by giving the above dielectric line converter to a second-kind dielectric line, a dielectric line unit using the second-kind dielectric line can be constructed so that a first-kind dielectric line can be directly connected to the dielectric line unit.

[0017] Further, in the present invention, the above dielectric line converter constitutes a directional coupler. For example, the two second-kind dielectric lines which are joined together or integrated constitute a directional coupler. In this way, a directional coupler into which input can be given through an NRD guide and which has a broad-band characteristic can be obtained.

[0018] Further, in the present invention, the above dielectric line unit or directional coupler to be used in the propagation portion of a transmission signal or reception signal constitutes a high-frequency circuit module.

[0019] Furthermore, in the present invention, the above high-frequency circuit module, and a transmission circuit and reception circuit constitute a transmitter-receiver.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Fig. 1 is a perspective view showing the construction of a dielectric line converter according to a first embodiment;

Fig. 2 shows a sectional view of each portion of the dielectric line converter;

Fig. 3 is a perspective view showing the construction of a dielectric line converter according to a second embodiment;

Fig. 4 is a perspective view showing the construction of a dielectric line converter according to a third embodiment;

Fig. 5 shows a sectional view of each portion of the dielectric line converter;

Fig. 6 shows the relationship of the characteristic impedance of the line to the space between the conductor surfaces;

Fig. 7 shows the reflection characteristic in a fixed frequency band;

Fig. 8 is a perspective view showing the construction of a dielectric line converter according to a fourth embodiment;

Fig. 9 shows a sectional view of each portion of the dielectric line converter;

Fig. 10 shows the relationship of the characteristic impedance of the line to the distance to the side conductor surface away from the dielectric stripline;

Fig. 11 shows the reflection characteristic in a fixed frequency band;

Fig. 12 is a perspective view showing an example of the construction of a directional coupler according to a fifth embodiment;

Fig. 13 is a top view of the directional coupler with the upper conductor plate removed;

Fig. 14 shows the distribution characteristic of the directional coupler;

Fig. 15 shows an example of the construction of a directional coupler according to a sixth embodiment;

Fig. 16 is a sectional view of each portion of the directional coupler;

Fig. 17 shows the construction of a directional coupler used in actual measurement;

Fig. 18 shows distribution characteristics obtained through simulation;

Fig. 19 shows distribution characteristics obtained by actual measurement;

Fig. 20 shows the construction of a millimeter wave radar module according to a seventh embodiment;

Fig. 21 is a block diagram of the millimeter wave radar module;

Fig. 22 shows the construction of a millimeter wave radar module according to an eighth embodiment;

Fig. 23 is a block diagram of the millimeter wave radar module;

Fig. 24 is a block diagram of a transmitter-receiver according to a ninth embodiment;

Fig. 25 is an exploded view in perspective showing an example of the construction of a dielectric line unit according to a tenth embodiment;

Fig. 26 is a perspective view and sectional views showing the construction of a dielectric line converter according to an eleventh embodiment; and

Fig. 27 is a perspective view showing the construction of a directional coupler according to a twelfth embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0021] The construction of a dielectric line converter according to a first embodiment of the present invention is shown in Figs. 1 and 2. Fig. 1A is a perspective view of the whole of the main part, and Fig. 1B is a perspective view of Fig. 1A in which the upper conductor plate is removed. And Fig. 2A is a sectional view taken on line A - A of Fig. 1A, and Fig. 1B is a sectional view taken on line B - B.

[0022] In Fig. 1, reference numerals 1 and 2 represent a conductor plate which is composed of an electrode film formed on the surface of a molded insulating plate or a conductor plate which is composed of a processed metal plate, respectively. Reference numeral 3 represents a dielectric stripline produced by injection molding or cutting work, which is made up of synthetic resin, ceramics, or their composite materials. As shown in the figure, by arranging the dielectric stripline 3 between the upper and lower conductor plates 1 and 2, a first-kind dielectric line, a second-kind dielectric line, and a line conversion portion therebetween are constructed.

[0023] The dimension in height and width direction of the dielectric stripline 3 is constant in any one of the first-kind dielectric line, second-kind dielectric line, and line conversion portion. As shown in Fig. 2, in the first-kind dielectric line portion, the space h between the opposing surfaces (conductor surfaces) of the upper and lower conductor plates is made to be smaller than the height dimension of the dielectric stripline 3. In this way, a hyper-NRD guide (indicated by HNRD in the figure) propagating a single LSM01 mode is constructed. In the second-kind dielectric line portion, the upper and lower conductor plates 1 and 2 are put one on another, that is, the space between the opposing surfaces is made to be nearly zero. Accordingly, the groove depth in the conductor plates of the second-kind dielectric line portion is set to be half of the height dimension of the dielectric stripline 3. In this way, the second-kind dielectric line is made a dielectric-loaded waveguide (indicated by DWG in the figure).

[0024] In the line conversion portion (indicated by TR in the figure), the groove depth is gradually changed so that the space between the opposing surfaces of the upper and lower conductor pates 1 and 2 becomes tapered over from the first-kind dielectric line portion to the second-kind dielectric line portion. Because of this construction, the reflection is reduced at the input-output portions or half-way, and a good reflection characteristic is maintained as a line converter.

[0025] Fig. 3 shows the construction of a dielectric line converter according to a second embodiment. Different from the first embodiment, in the example shown in Fig. 3, the space between the opposing surfaces of the upper and lower conductor plates 1 and 2 of the line conversion portion is changed stepwise from the space in the first-kind dielectric line portion to the space (nearly zero) in the second-kind dielectric line portion. In such a construction also, as the space difference in the portion in which the space between the opposing surfaces of the upper and lower conductor plates 1 and 2 changes stepwise is small, the reflection is suppressed to be low, and the total reflection characteristic can be kept good.

[0026] Next, the construction of a dielectric line converter according to a third embodiment is explained with reference to Figs. 4 through 7.

[0027] Fig. 4A is a perspective view of the whole of the main part, and Fig. 4B is a perspective view of Fig. 4A in which the upper conductor plate is removed. Reference numerals 1 and 2 represent a conductor plate, and reference numeral 3 represents a dielectric stripline. This dielectric stripline is made up of synthetic resin, ceramics, or their composite materials, and PTFE of dielectric constant $\varepsilon r = 2.04$ is used in the examples showing characteristics to be described later.

[0028] A sectional view of each portion is shown in Fig. 5. Fig. 5A is a sectional view in the first-kind dielectric line portion, Fig. 5B is a sectional view in the line conversion portion, and Fig. 5C is a sectional view in the second-kind dielectric line portion. The height and width of the dielectric stripline 3 are 2.2 mm and 1.8 mm, respectively, and are constant in any of the first-kind dielectric line, second-kind dielectric line, and line conversion portion. The groove depth given in the conductor plate of the first-kind dielectric line portion is made 0.5 mm, the groove depth in the line conversion portion is 0.65 mm, and the groove depth in the second-kind dielectric line is 1.1 mm.

[0029] Here, the relationship of the characteristic impedance of the line to the space between the conductor surfaces of the upper and lower conductor plates 1 and 2 is shown in Fig. 6. Z1 represents the characteristic impedance of the first-kind dielectric line, and Z2 represents the characteristic impedance of the second-kind dielectric line. When the space between the conductor surfaces is determined so that the characteristic impedance of the line conversion portion is given by $\sqrt{(Z1 \cdot Z2)}$, the impedance matching between the lines of the two kinds can be realized. In this example, the space between the conductor surfaces is 0.9 mm. And when the wavelength on the line is assumed to be λg, the line length L of the line conversion portion is set to

be λg/4 or an odd multiple of λg/4. In the example, the wavelength is in a 60 GHz band and L is 1.85 mm.

[0030] Fig. 7 shows the reflection characteristic of a dielectric line converter constructed as in the above which is based on the three-dimensional finite element method. In this way, a low reflection characteristic of -30 dB can be obtained in a 60 GHz band.

[0031] Next, the construction of a dielectric line converter according to a fourth embodiment is explained with reference to Figs. 8 through 11.

[0032] Fig. 8 is a perspective view of a dielectric line converter with the upper conductor plate removed. In this example, the space between the upper and lower conductor plates of a first-kind dielectric line portion is kept constant, and the space between the upper and lower conductor plates of a second-kind dielectric line is made nearly zero. However, in a line conversion portion, the groove is expanded toward the side of a dielectric stripline 3, and the groove depth in that portion is made the same as the groove depth of the conductor plate in the first-kind dielectric line.

[0033] A sectional view of each portion of the above dielectric line converter is shown in Fig. 9. Fig. 9A is a sectional view of the first-kind dielectric line portion, Fig. 9B is a sectional view of the line conversion portion, and Fig. 9C is a sectional view of the second-kind dielectric line portion. The height and width of the dielectric line 3 are 2.2 mm and 1.8 mm, respectively, and are constant in any of the first-kind dielectric line, second-kind dielectric line, and line conversion portion. The groove depth given in the conductor plate of the first-kind dielectric line portion is made 0.5 mm. The groove depth in the line conversion portion is also 0.5 mm, but the space to the side conductor surface in the line conversion portion is made 0.16. The groove depth in the second-kind dielectric line is 1.1 mm.

[0034] Here, the relationship of the characteristic impedance of the line to the distance from the dielectric stripline to the side conductor surface is shown in Fig. 10. Z1 represents the characteristic impedance of the first-kind dielectric line, and Z2 represents the characteristic impedance of the second-kind dielectric line. When the space from the dielectric stripline to the side conductor surface is determined so that the characteristic impedance of the line conversion portion is given by $\sqrt{(Z1 \cdot Z2)}$, the impedance matching between the lines of the two kinds can be realized. In this example, the space is 0.16 mm. And when the wavelength on the line is assumed to be λg, the line length L of the line conversion portion is set to be λg/4 or an odd multiple of λg/4. In the example, the wavelength is in a 60 GHz band and L is 1.83 mm.

[0035] Fig. 11 shows the reflection characteristic of a dielectric line converter constructed as in the above which is based on the three-dimensional finite element method. In this way, a low reflection characteristic of -30 dB can be obtained in a 60 GHz band.

[0036] Next, an example of the construction of a directional coupler according to a fifth embodiment is explained with reference to Figs. 12 through 14.

[0037] Fig. 12 is a perspective view of a directional coupler with the upper conductor plate removed, and Fig. 13 is its top view. The portions indicated by 31, 32, 33, and 34 are dielectric striplines, and in the example they are integrally molded substantially in a H-shape. In the conductor plate 1 grooves in which the dielectric stripline 31 through 34 are fitted to a certain depth are formed. The upper conductor plate also has the same construction.

[0038] As constructed this way, over from the dielectric stripline 32 to dielectric stripline 34, the line conversion takes place in order of the first-kind dielectric line, line conversion portion, second-kind dielectric line, line conversion portion, and first-kind dielectric line. In like manner, over from the dielectric stripline 31 to 33, the line conversion takes place in order of the first-kind dielectric line, line conversion portion, second-kind dielectric line, line conversion portion, and first-kind dielectric line.

[0039] The above dielectric striplines are integrated in a part of the portion constituting the second-kind dielectric line. Because of this, the second-kind dielectric line portion is made to function as a directional coupler of DWG. The directional coupler of DWG shows a broad-band characteristic just as the directional coupler using a cavity waveguide is broad-band. Furthermore, as the four parts can be used as hyper-NRDs, when a directional coupler is given in a dielectric line circuit using a hyper-NRD guide, the whole of them can be made greatly small-sized.

[0040] In the above directional coupler, the space between the upper and lower conductor plates of the first-kind and second-kind dielectric line portion and the space between the upper and lower conductor plates of the line conversion portion are the same as in the example shown as the third embodiment in Fig. 5. And the dimension and material of the dielectric striplines are the same as in the third embodiment. The dimension of each portion shown in Fig. 13 is the values of a directional coupler designed for a 60 GHz band, and they are expressed in a unit of mm.

[0041] Fig. 14 shows the distribution characteristic based on the three-dimensional finite element method. Thus, in the 60 GHz band as a designed band S31 and S41 characteristics are within -3 dB to result in an equal distribution characteristic, and, furthermore, the characteristic is maintained over a broad band.

[0042] Next, an example of a directional coupler according to a sixth embodiment is explained with reference to Figs. 15 through 19.

[0043] Fig. 15 is a top view of a directional coupler with the upper conductor plate removed. The directional coupler is basically the same as what is shown in Fig. 13, but the directional coupler to be used in a 76 GHz band is shown here. As the directional coupler is used in the higher frequency band, the line length of the TR

conversion portion is made 1.3 mm and in the second-kind dielectric line portion the dimension of the portion to couple the parallel-wire lines is made smaller than shown in Fig. 13.

[0044] Fig. 16 shows the sectional view of the line portions of the three kinds in the above directional coupler. Fig. 16A is a sectional view of the first-kind dielectric line portion, Fig. 16B is a sectional view of the line conversion portion, and Fig. 16C is a sectional view of the second-kind dielectric line portion. As the directional coupler is used in the higher frequency band, the dimension of each portion is made smaller than shown in Fig. 5.

[0045] Fig. 17 shows the constriction of a directional coupler the characteristics of which were practically investigated, and is a top view of only the dielectric stripline portion. In this directional coupler, the power of the input signal from port No. 1 is distributed to No. 2 and No. 3. Because a hyper-NRD guide is entirely constituted outside the conversion portion TR, even if a bend of an arbitrary curvature is constructed, any loss accompanying mode conversion does scarcely occur. In the example, a bend having a radius of curvature of 5 mm (R5) is formed in order to lead out port No. 4 in a direction at a right angle to a straight line connecting port No.1 and port No. 3.

[0046] Fig. 18 shows the result of the directional coupler shown in Fig. 15 which was simulated as no loss system using the three-dimensional finite element method. Fig. 19 is the result of an actual measurement of the directional coupler shown in Fig. 17. It is able to make the power distribution ratio nearly constant over such a broad frequency band.

[0047] Next, based on Figs. 20 and 21, an example of the construction of a millimeter wave radar module according to a seventh embodiment is explained. Fig. 20 is a top view of the module with the upper conductor plate removed, and Fig. 21 a block diagram of the above millimeter wave radar module.

[0048] The millimeter wave radar module is principally made up of each unit of oscillator, isolator, directional coupler, circulator, and mixer. In the oscillator, a millimeter wave signal is generated by a Gunn diode. The isolator is made up of a terminator connected to one port of the circulator which port three dielectric striplines as shown in the figure. That is, in the isolator, the millimeter wave signal from the oscillator is made propagated to the side of the directional coupler, and it is arranged that the reflected signal from the directional coupler is lead to the terminator. The directional coupler is of the same construction as that shown in Fig. 12, and is given the four ports of a hyper-NRD guide to distribute an input signal from port No. 1 to port No. 3 and port No. 4 in a fixed power distribution ratio. The signal from port No. 3 is radiated as a TX signal toward a target from an antenna connected to an RF port through the circulator. The reflected signal from the target which the antenna received is input as an RX signal to the mixer through the circulator. On the other hand, a signal from port No. 4 of the directional coupler is input to the mixer as an LO signal, and the mixer mixes the RF signal and LO signal. When the signal from the oscillator has two-valued frequencies f1 and f2 over the course of time, an IF signal having a frequency component of f1 - f2 in accordance with the time difference caused by the path difference between two paths can be obtained. By processing this IF signal, the distance to the target is measured.

[0049] Next, the construction of a millimeter wave radar module according to an eighth embodiment is shown in Fig. 22 and 23. Fig. 22 is a top view with the upper conductor plate removed, and Fig. 23 is a block diagram of the above millimeter wave radar module.

[0050] The millimeter wave radar module is principally made up of each unit of oscillator, isolator, directional coupler, circulator, up-converter, and down converter. In the oscillator, a millimeter wave signal is generated by a Gunn diode. The isolator is made up of a terminator connected to one port of the circulator which port three dielectric striplines as shown in the figure, and in the isolator the millimeter wave signal from the oscillator is made propagated to the side of the directional coupler and it is arranged that the reflected signal from the directional coupler is lead to the terminator. The signal input from port No. 1 of the directional coupler is output from port No. 3 and port No. 4, respectively, and input to the up-converter and the down converter. The up-converter mixes an LO signal from the directional coupler and an IF signal from an IF circuit, and outputs a signal containing a frequency signal of LO and IF to the circulator. This signal is radiated outside as a TX signal through the circulator. In this example, the signal is output to a waveguide through a WG converter to convert a hyper-NRD guide to a waveguide mode. The signal reflected from a target is input as an RX signal into the down converter through the circulator. The down converter mixes the LO signal oscillated in the oscillator and the RX signal and an IF signal containing an RX - LO component is obtained. By processing the frequency change of the IF signal given to the above up-converter and the frequency component of the IF signal obtained from the down converter, the distance to the target is measured.

[0051] Fig. 24 is a block diagram showing the construction of the whole of a transmitter-receiver according to a ninth embodiment, in which the above millimeter wave radar module is used. In Fig. 24, the RF circuit corresponds to the above millimeter wave radar module, and the IF circuit is made up of a filter circuit and AD converter for the IF signal obtained from the millimeter wave radar module. The signal processing circuit measures the distance from the antenna of the millimeter wave radar module to the target and calculates the relative speed by signal-processing or computing the digital data of the IF signal, and when required external circuits of mobile engine control units, and so on, are controlled.

[0052] Next, the construction of a dielectric line unit

according to a tenth embodiment is shown in Fig. 25. In Fig. 25, reference numerals 1 and 2 represent upper and lower conductor plates, and 3a and 3b represent divided upper and lower dielectric striplines. Further, 4 represents a board in which a microstrip line 5, and so on, are formed, and the board sandwiched between the upper and lower conductor plates 1 and 2 constitutes a dielectric line unit. This dielectric line unit corresponds to a unit having the construction shown in Fig. 4 which is divided up and down at the middle portion and sandwiches the board therebetween.

[0053] By the microstrip line 5 inserted in a DWG portion in a direction at a right angle to the line of the DWG, a line conversion between the DWG and microstrip line is performed. And generation of unwanted waves is reduced by such a line conversion between the DWG and microstrip line, compared with the case in which a direct line conversion between an NRD guide and microstrip line is carried out. More, a hollow portion is formed in the portion of the conductor plate 2 which is opposed to the microstrip line 5 so that the microstrip line 5 is not made in direct contact with the upper conductor plate 2.

[0054] More, in each of the embodiments shown in the above, an example in which a line conversion between a hyper-NRD guide and dielectric-loaded waveguide is performed was shown. However, when a line conversion between a normal NRD guide and dielectric-loaded waveguide in which both modes of a LSM01 mode and LSE01 mode are propagated is carried out, the present invention can be equally applied. The example is shown in Fig. 26.

[0055] In Fig. 26A is a perspective view of the whole of the main part, Fig. 26B is a sectional view taken on line B - B of Fig. 26A, and Fig. 26C is a sectional view taken on line C - C of Fig. 26A. Different from the construction shown in Fig. 1, no groove is given in the upper and lower conductor plates 1 and 2 of the normal NRD guide in this example.

[0056] In the line conversion portion (TR), the groove depth is gradually changed so that the space between the opposing surfaces of the upper and lower conductor plates 1 and 2 becomes tapered over from the normal NRD guide portion to the DWG portion.

[0057] Further, in each of the embodiments shown in the above, the conductor surface of a dielectric line was made up of the surface of a conductor plate. However, the conductor surface may be formed by metallizing a fixed portion of a dielectric stripline. Regarding a directional coupler, the example is shown in Fig. 27.

[0058] Fig. 27A is a perspective view of a dielectric stripline, and Fig. 27B is a perspective view of the directional coupler with the upper conductor plate removed. The portions indicated by 31, 32, 33, and 34 are dielectric lines, but different from the example shown in Fig. 12 an electrode film is formed on a dielectric stripline portion constituting the DWG. The construction of the others is the same as in Fig. 12.

[0059] Because of this construction, in the DWG portion the metallized electrode functions as a conductor surface, and accordingly even if a more or less spacing is caused between the dielectric stripline and the conductor plate in the DWG portion a stable characteristic can be always realized.

[0060] According to a first aspect of the present invention, because the discontinuity portion over from a first-kind dielectric line to a second-kind dielectric line is lessened, a line conversion is made without deterioration of reflection characteristics. Furthermore, as the line does not tend to be widened in its width direction, a dielectric line converter which is small-sized in its width direction can be obtained.

[0061] According to a second aspect of the present invention, the reflection at the discontinuity portion of the line over from a first-kind dielectric line to a second-kind dielectric line is more suppressed.

[0062] According to a third and fifth aspect of the present invention, reflected waves at two discontinuity portions are superposed in opposite phase, and as a result the reflected waves are canceled. Because of this the reflection characteristic is improved.

[0063] According to a fourth aspect of the present invention, because the space between the upper and lower conductor surfaces sandwiching a dielectric stripline is changed stepwise over from a first-kind dielectric line to a second-kind dielectric line, the dimension in length direction of a line converter which is short suffices. Therefore, a line converter which is short in its length direction can be obtained.

[0064] According to a sixth aspect of the present invention, a dielectric line circuit having an NRD guide and DWG which practically do not cause any loss accompanying the mode conversion in a bend can be easily constructed.

[0065] According to a seventh aspect of the present invention, when, for example, an element of a DWG is given to a dielectric line circuit, the element becomes possible to be directly connected in a dielectric line circuit of an NRD guide, and as a result it becomes possible to make the whole of small size.

[0066] According to an eighth aspect of the present invention, because input and output can be done at NRD guides and a directional coupler of a DWG can be constructed, a directional coupler having broad-band characteristics and of small size can be realized.

[0067] According to a ninth aspect of the present invention, a small-sized high-frequency circuit module having broad-band characteristics in which the directional coupler or dielectric line unit is used in the propagation portion of a transmission signal or reception signal can be easily constructed.

[0068] According to a tenth aspect of the present invention, a small-sized transmitter-receiver having broad-band characteristics in which the high-frequency circuit module, transmission circuit, and reception circuit are given can be constructed.

[0069] While the invention has been particularly shown and described with reference to preferred embodiments, it will be understood by those skilled in the art that the foregoing and other changes in form and details can be made without departing from the spirit and scope of the invention.

Claims

1. A dielectric line converter comprising a line converter made up of a first-kind dielectric line having upper and lower surfaces as a conductor surface of a dielectric stripline (3) and spaces beside the dielectric stripline (3) and a second-kind dielectric line having upper and lower surfaces and side surfaces as a conductor surface of a dielectric stripline (3), and a dielectric stripline (3) connected to the dielectric striplines (3) of the first-kind and second-kind dielectric line or being continuous with the dielectric striplines of the first-kind and second-kind dielectric line, wherein the space between the upper and lower conductor surfaces in the region except the dielectric striplines (3) is made narrower than the space between the upper and lower conductor surfaces in the first-kind line, and wherein the space between the conductor surfaces in the second-kind dielectric line portion is made nearly zero.

2. A dielectric line converter as claimed in claim 1, wherein when the further the position is displaced from the first-kind dielectric line to the second-kind dielectric line, the narrower the space is made.

3. A dielectric line converter as claimed in claim 1, wherein the line length between the first-kind dielectric line and the second-kind dielectric line is made nearly an odd multiple of a fourth of a wavelength on the line, and wherein in the line between the first-kind dielectric line and the second-kind dielectric line the space between the upper and lower conductor surfaces is made a fixed space which is narrower than the space between the upper and lower conductor surfaces in the first-kind dielectric line.

4. A dielectric line converter comprising a line converter made up of a first-kind dielectric line having upper and lower surfaces as a conductor surface of a dielectric stripline (3) and spaces beside the dielectric stripline (3) and a second-kind dielectric line having upper and lower surfaces and side surfaces as a conductor surface of a dielectric stripline (3), and a dielectric stripline (3) connected to the dielectric striplines (3) of the first-kind and second-kind dielectric line or being continuous with the dielectric striplines (3) of the first-kind and second-kind dielectric line, wherein the space from the dielectric stripline (3) to the side conductor surface is made a fixed value which is narrower than the space from the dielectric stripline (3) of the first-kind dielectric line to the side conductor surface.

5. A dielectric line converter as claimed in claim 4, wherein the line length between the first-kind dielectric line and the second-kind dielectric line is made an odd multiple of a fourth of a wavelength on the line.

6. A dielectric line converter as claimed in claims 1 - 6, wherein the space between the conductor surfaces of the first-kind dielectric line is made narrower than the height of the dielectric stripline (6) of the first-kind dielectric line so that the cutoff frequency of LSM01 mode becomes lower than the cutoff frequency of LSE01 mode and as a result the first-kind dielectric line is made a dielectric line propagating a single mode of LSM01 mode.

7. A dielectric line unit comprising a dielectric line converter as claimed in claims 1 - 6.

8. A directional coupler comprising a dielectric line converter as claimed in claims 1 - 6.

9. A high-frequency circuit module in which a dielectric line unit as claimed in claim 7 or a directional coupler as claimed in claim 8 is used in the propagation portion of a transmission signal or reception signal.

10. A Transmitter-receiver comprising a high-frequency circuit module as claimed in claim 9 and a transmission circuit and reception circuit.

FIG. 1A

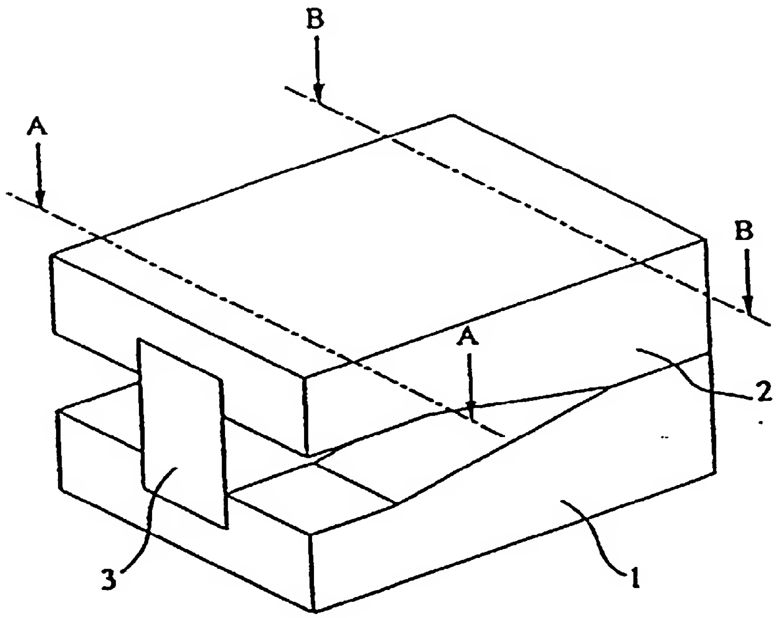


FIG. 1B

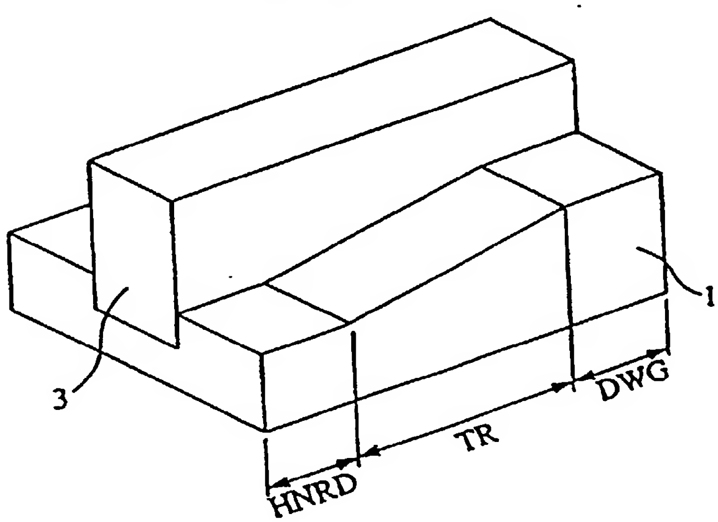


FIG. 2A

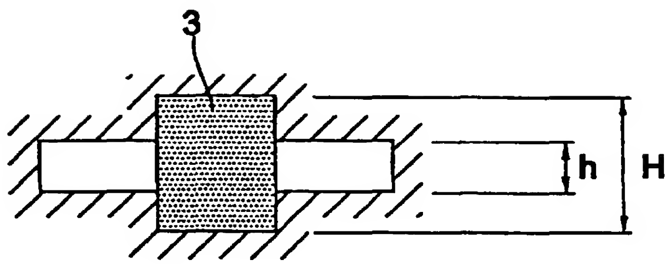


FIG. 2B

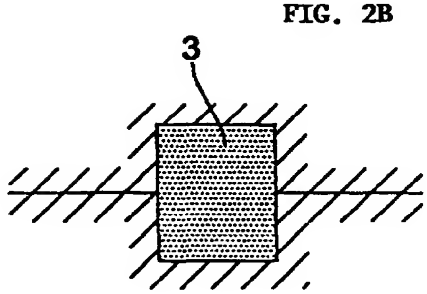


FIG. 3A

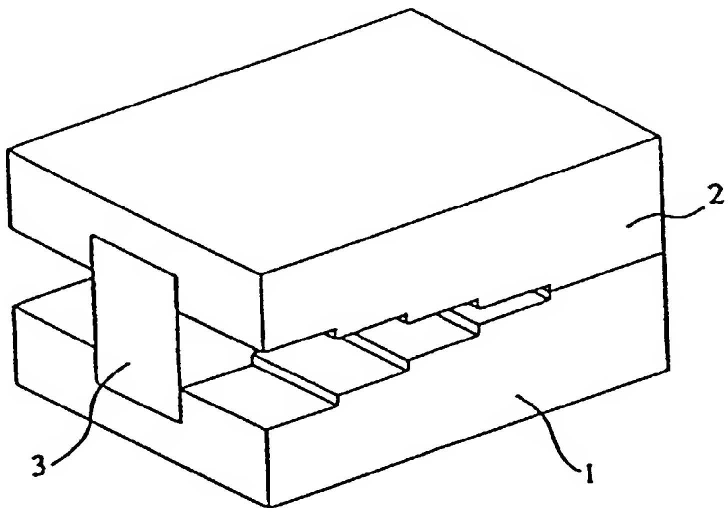


FIG. 3B

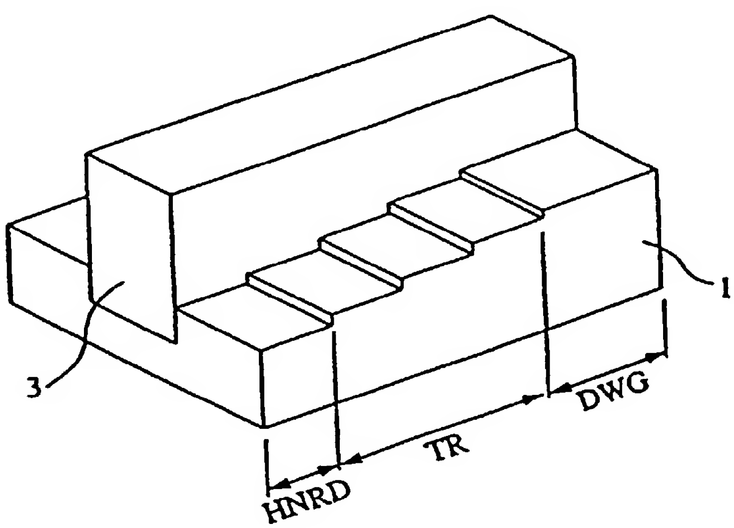


FIG. 4A

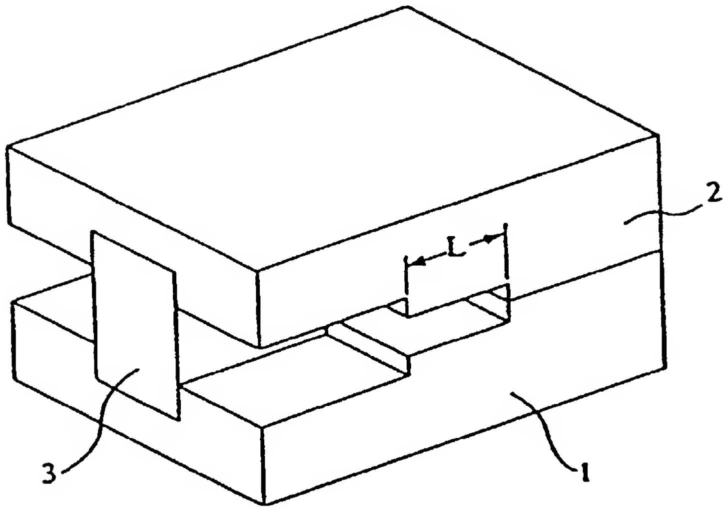


FIG. 4B

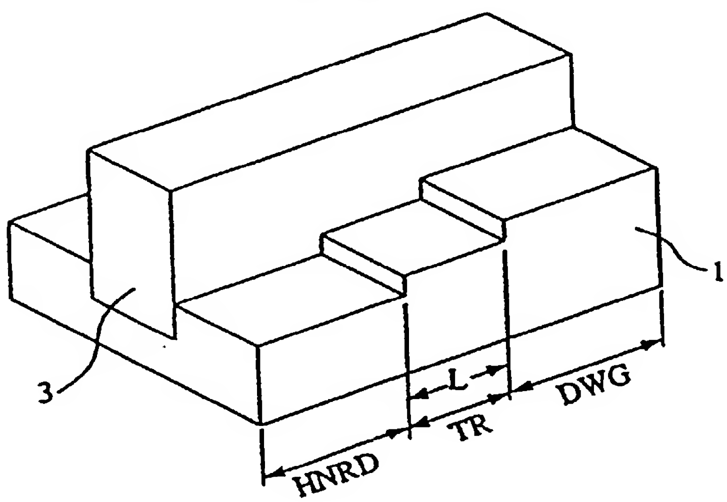


FIG. 5A

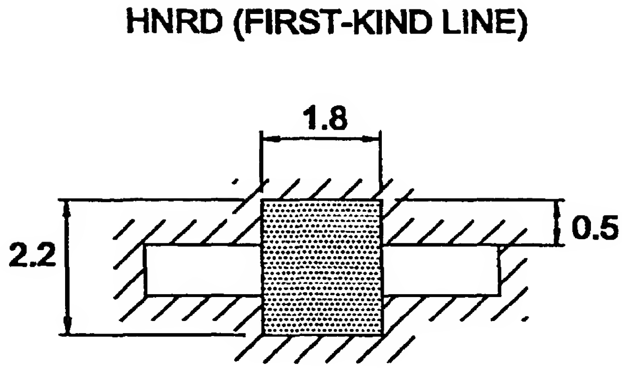


FIG. 5B

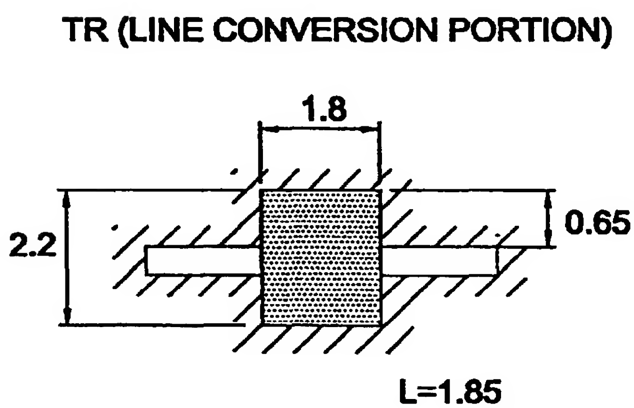


FIG. 5C

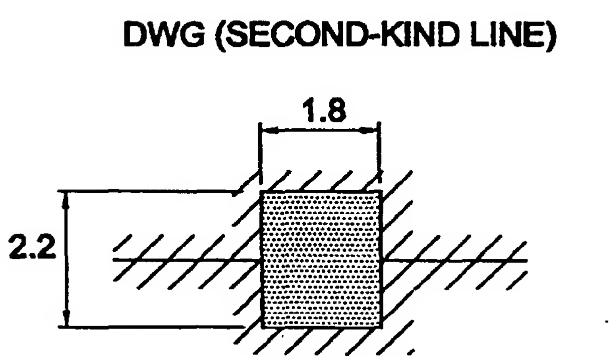
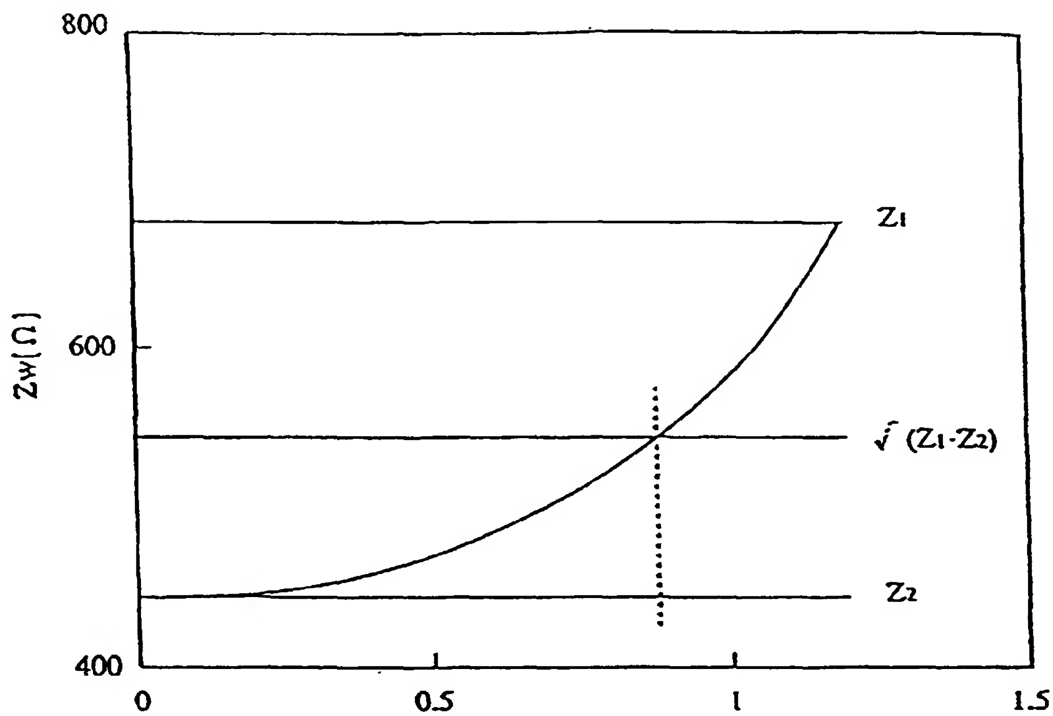


FIG. 6



SPACE BETWEEN CONDUCTOR SURFACES (GAP) [mm]

FIG. 7

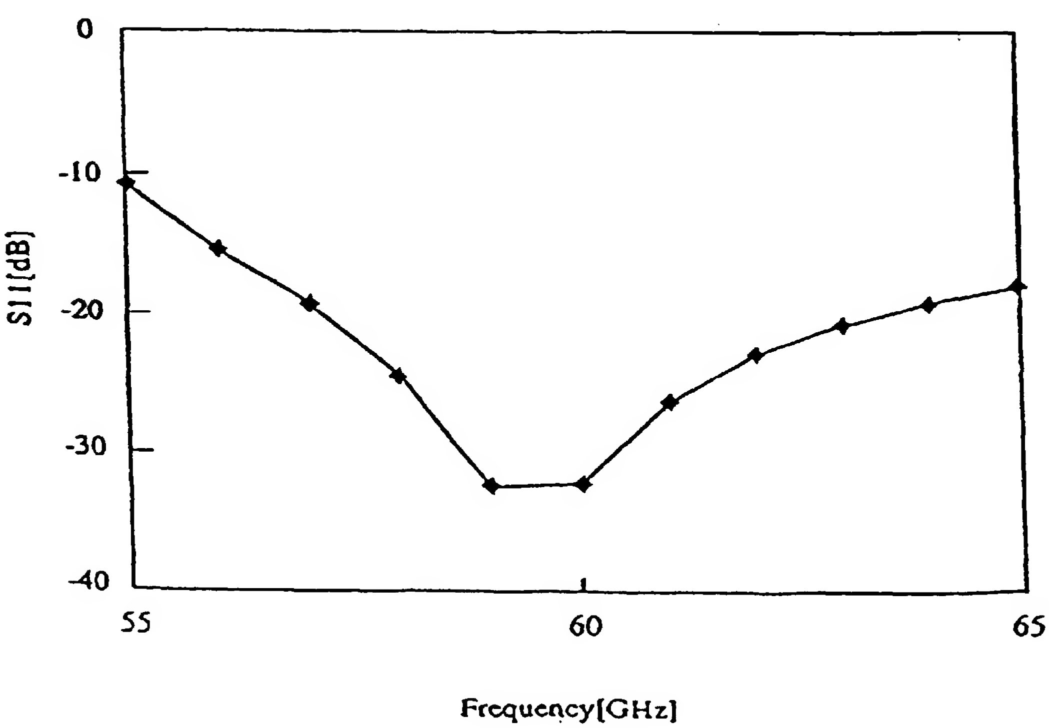


FIG. 8

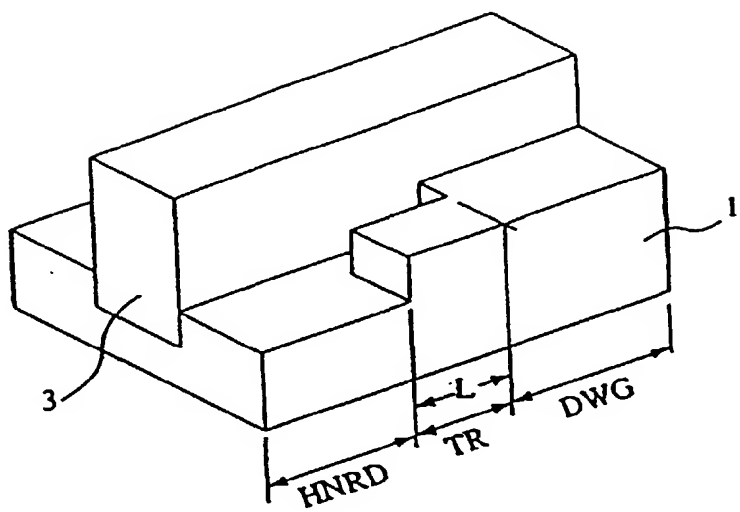


FIG. 9A

HNRD (FIRST-KIND LINE)

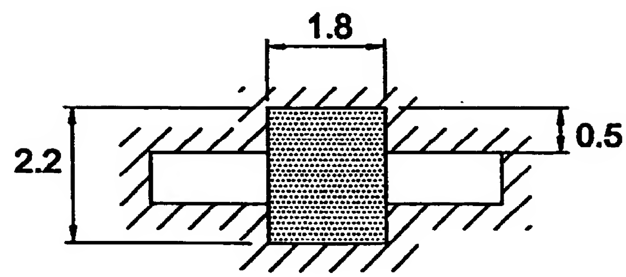


FIG. 9B

TR (LINE CONVERSION PORTION)

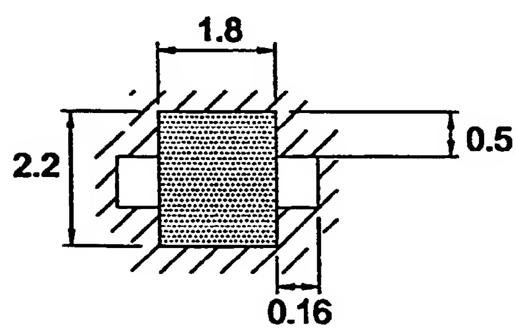


FIG. 9C

DWG (SECOND-KIND LINE)

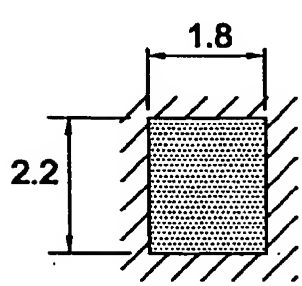
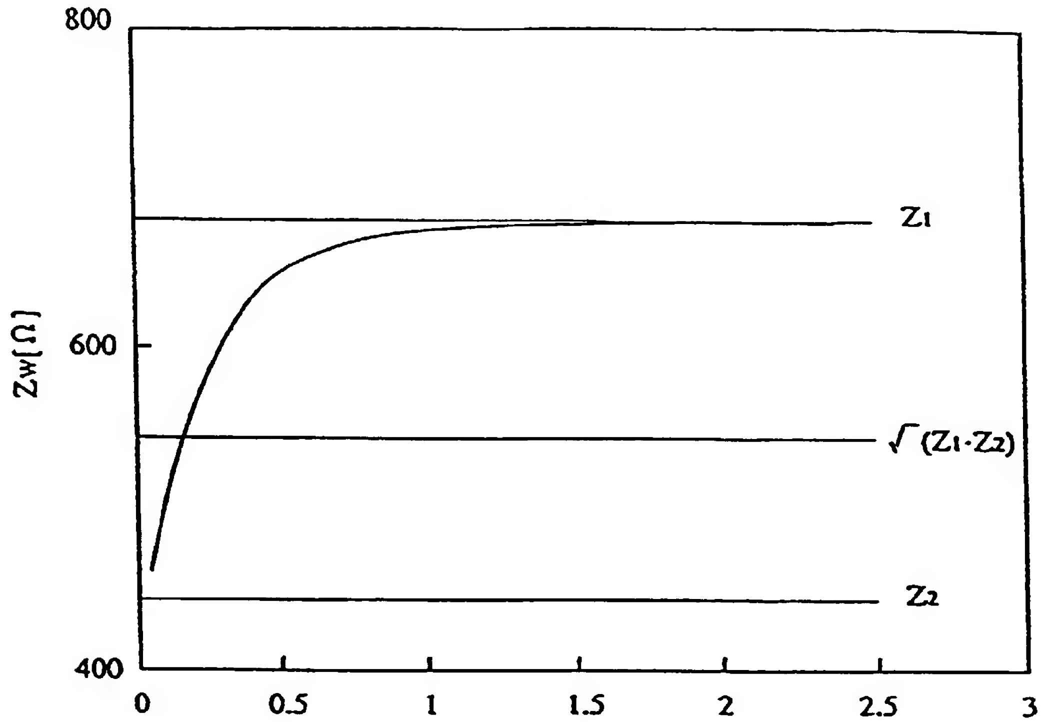


FIG. 10



DISTANCE TO SIDE CONDUCTOR SURFACE [mm]

FIG. 11

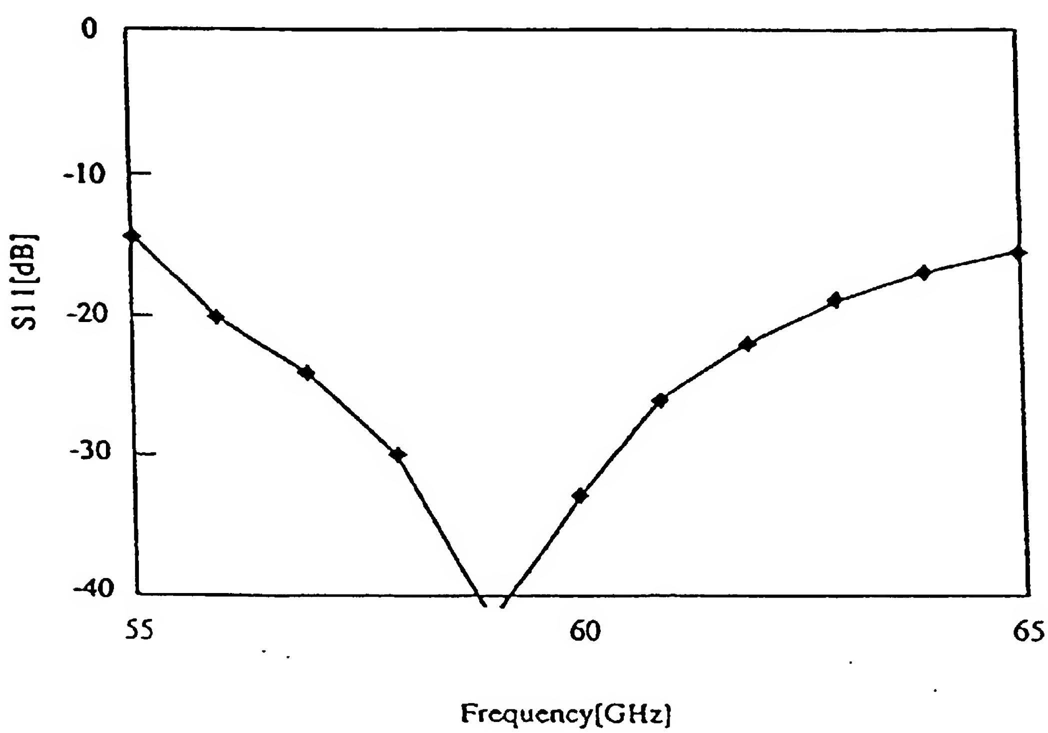


FIG. 12

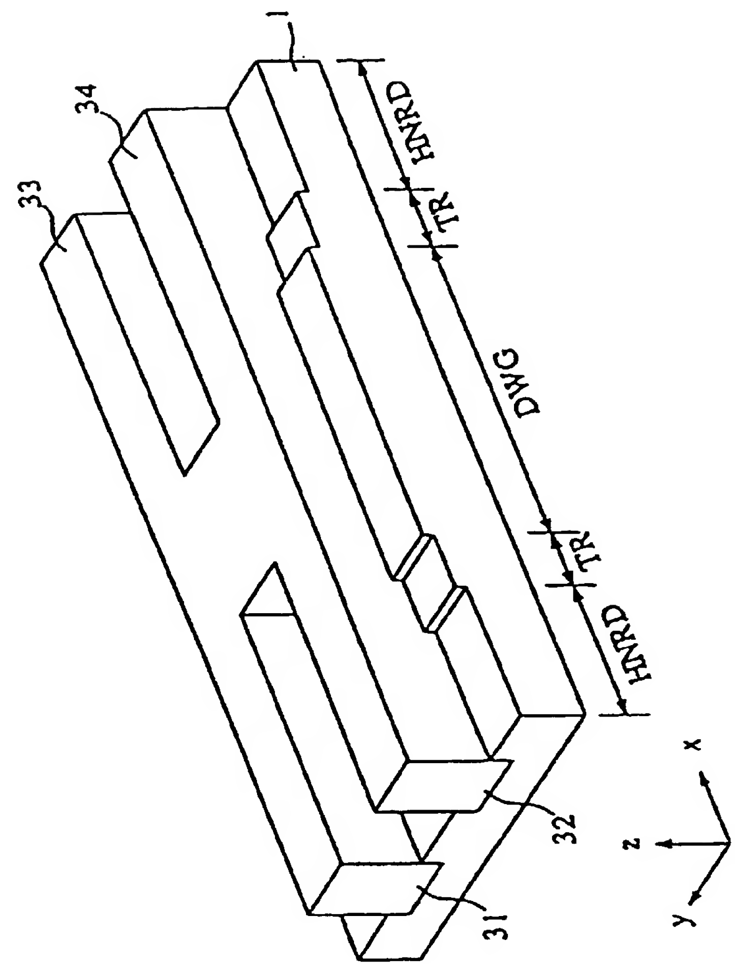


FIG. 13

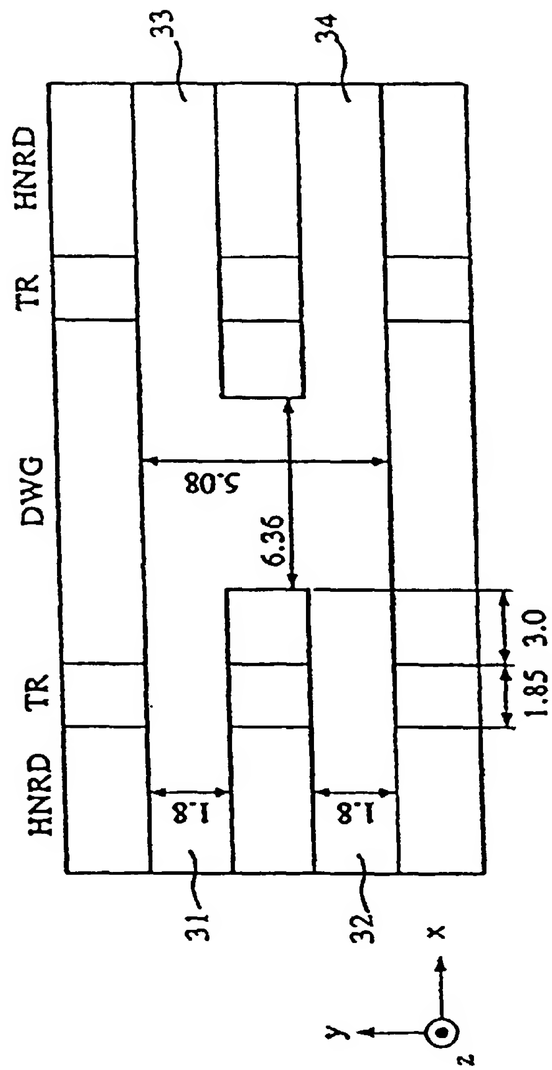


FIG. 14

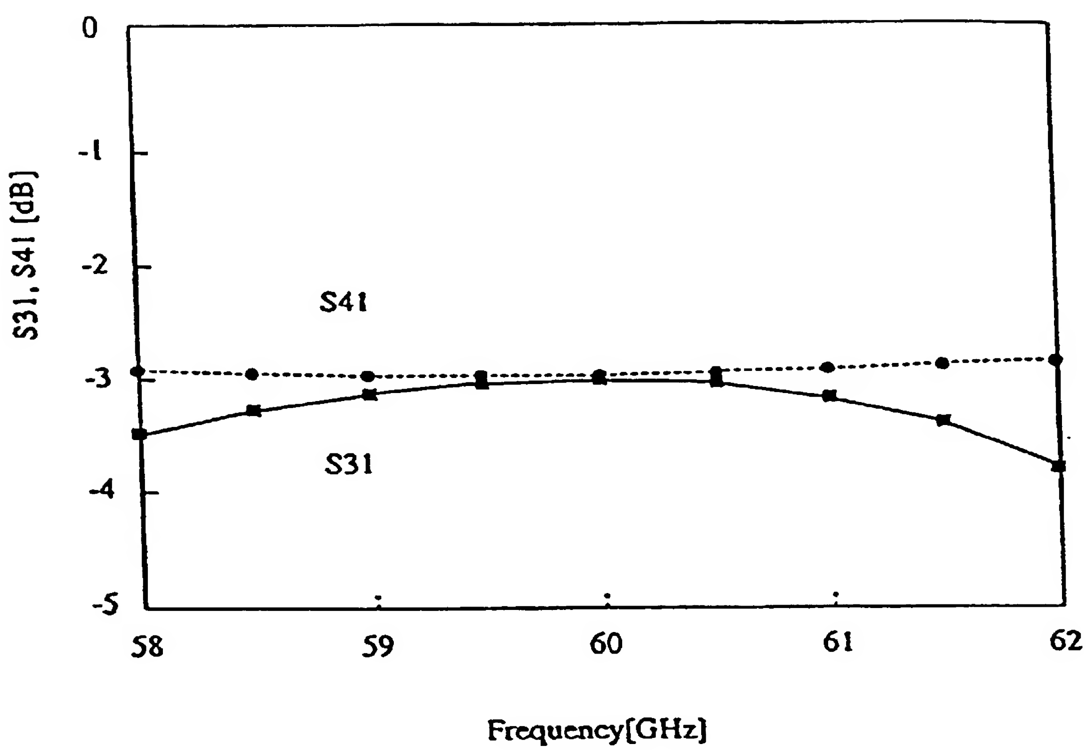


FIG. 15

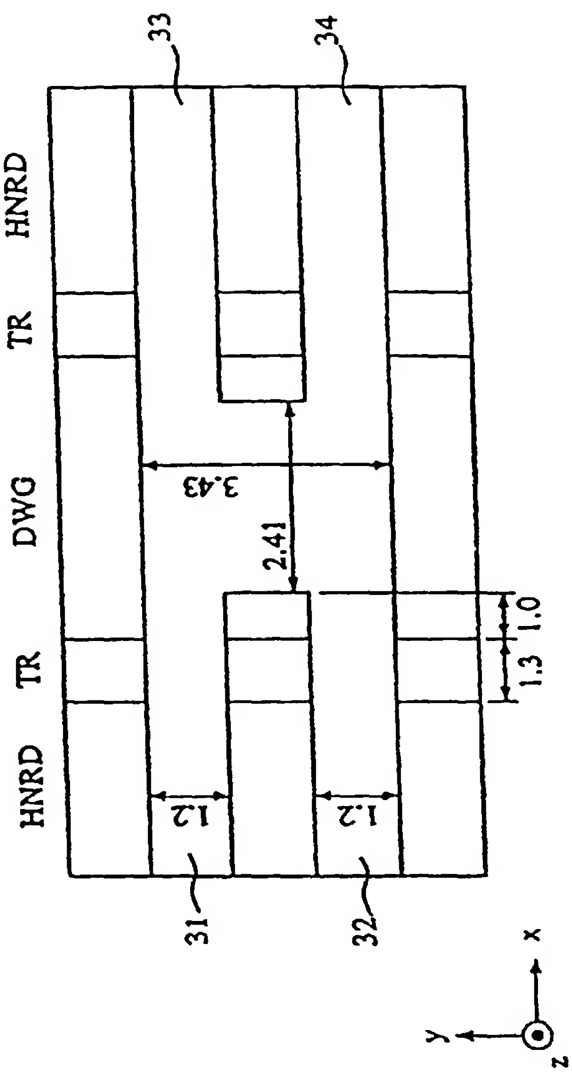


FIG. 16A

HNRD (FIRST-KIND LINE)

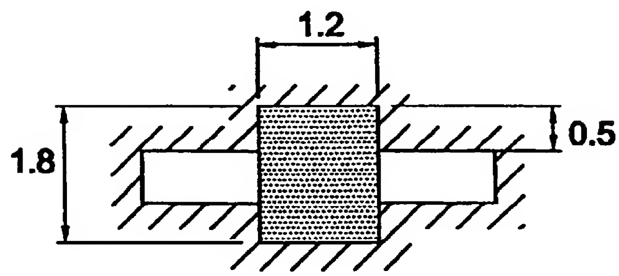


FIG. 16B

TR (LINE CONVERSION PORTION)

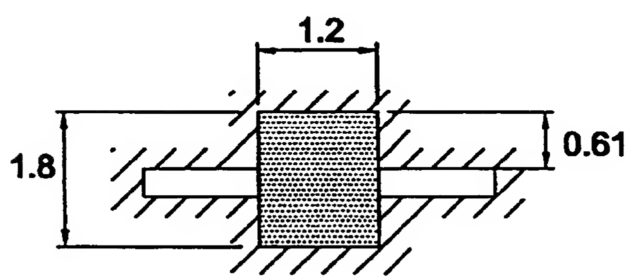


FIG. 16C

DWG (SECOND-KIND LINE)

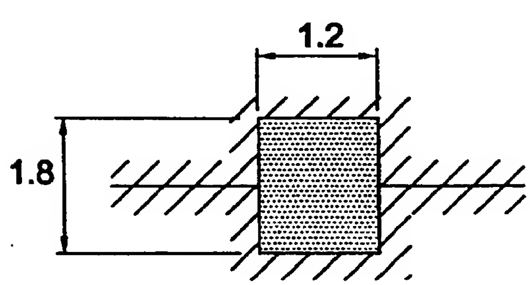


FIG. 17

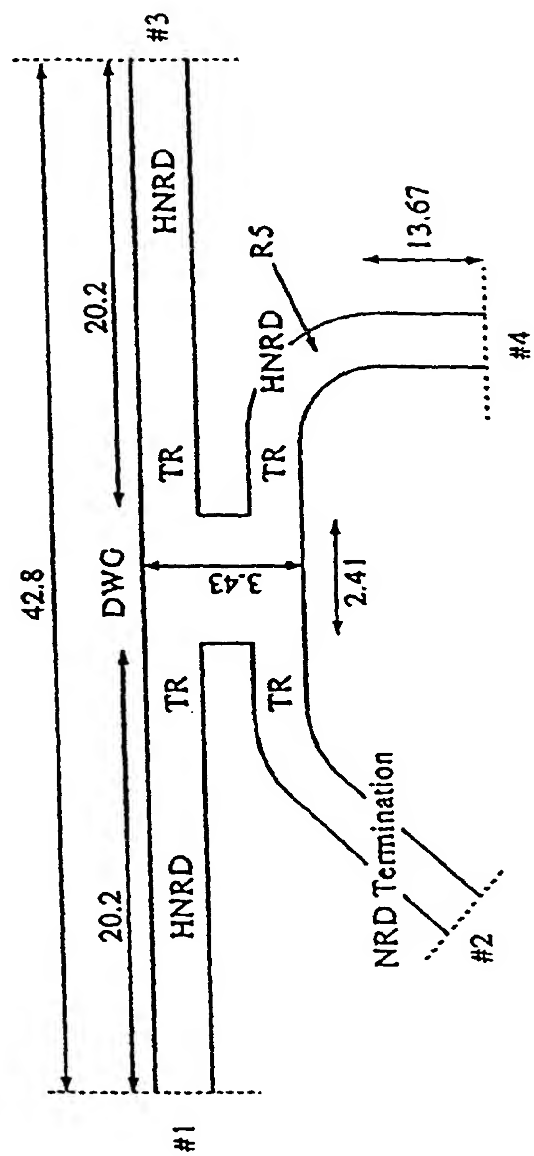

#3
HNRD
20.2
42.8
DWG
TR
TR
HNRD
R5
13.67
#4
3.43
2.41
TR
TR
HNRD
20.2
NRD Termination
#2
#1

FIG. 18

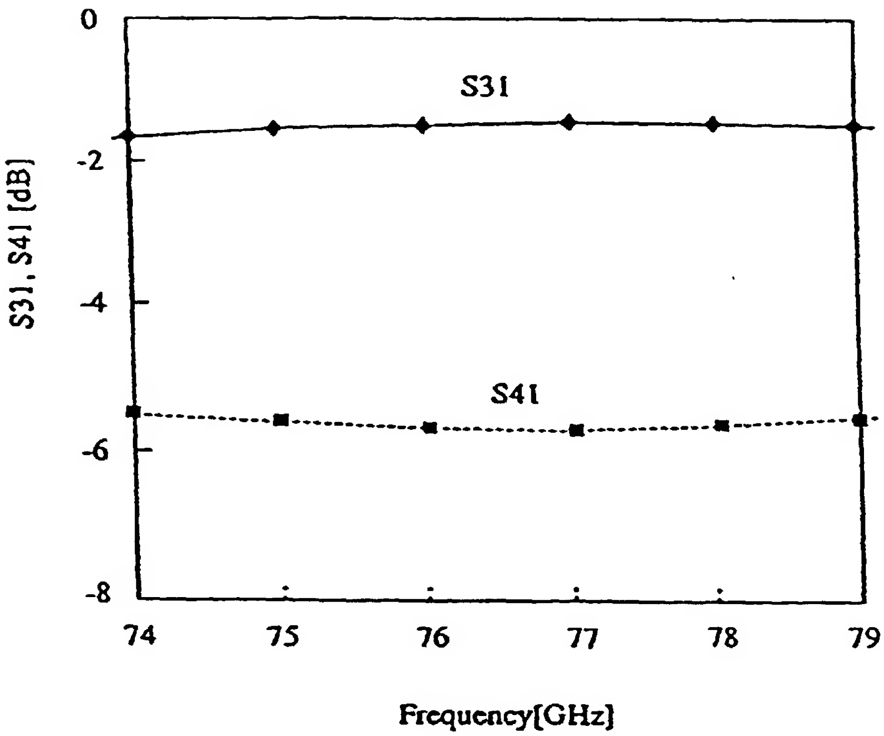

0
-2
-4
-6
-8
S31
S41
S31, S41 [dB]
74
75
76
77
78
79
Frequency[GHz]

FIG. 19

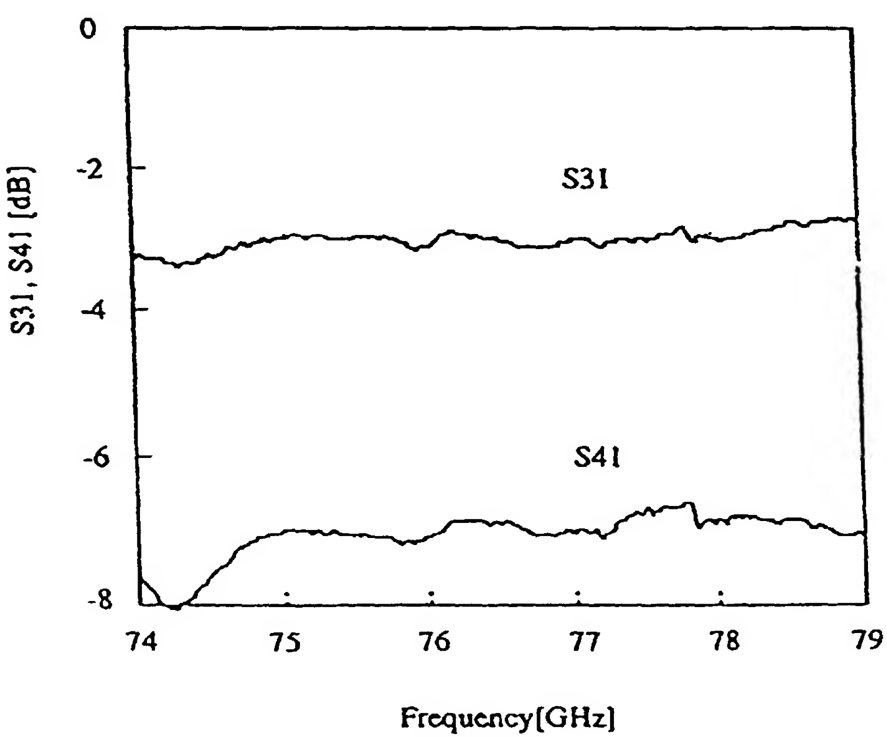

0
-2
-4
-6
-8
S31
S41
S31, S41 [dB]
74
75
76
77
78
79
Frequency[GHz]

FIG. 20

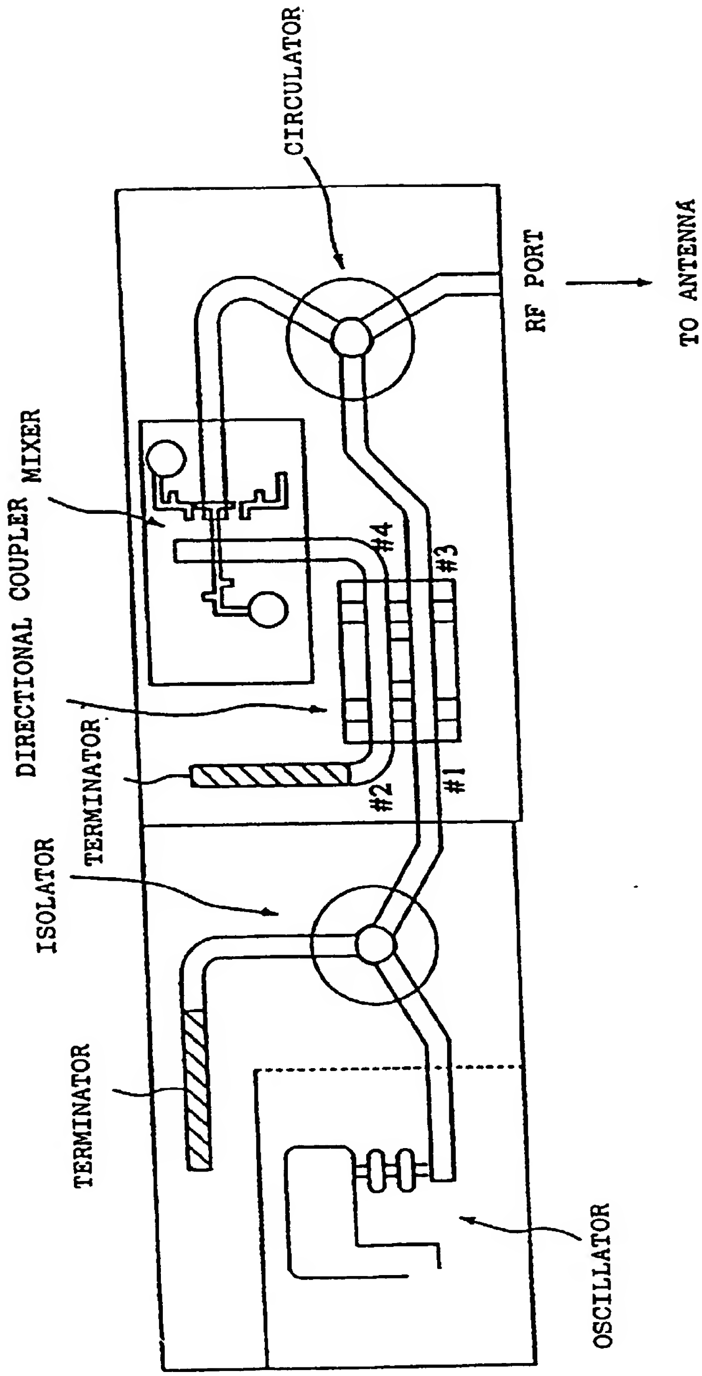

CIRCULATOR
RF PORT
TO ANTENNA
MIXER
DIRECTIONAL COUPLER
TERMINATOR
#1
#2
#3
#4
ISOLATOR
TERMINATOR
OSCILLATOR

FIG. 21

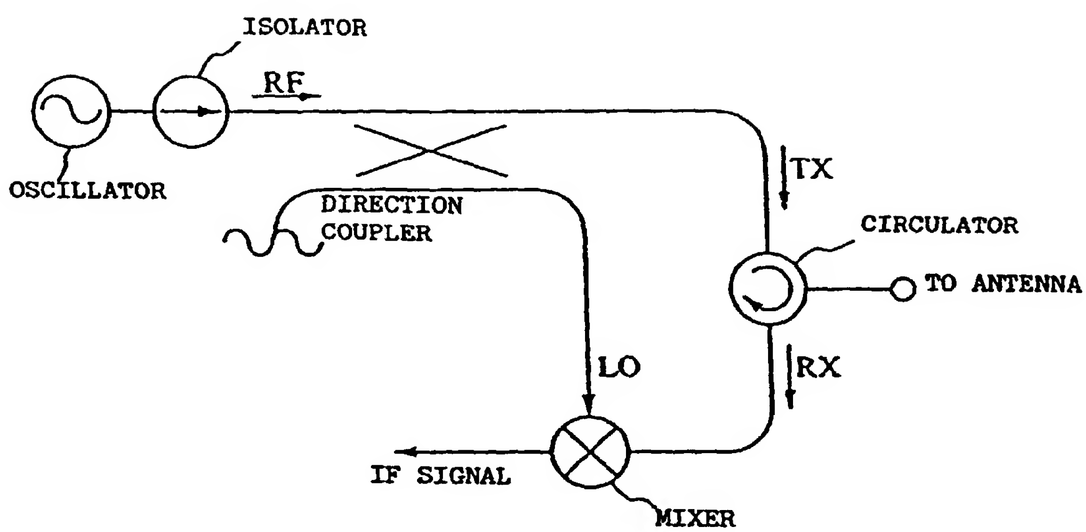

ISOLATOR
RF
OSCILLATOR
TX
DIRECTION
COUPLER
CIRCULATOR
TO ANTENNA
LO
RX
IF SIGNAL
MIXER

FIG. 22

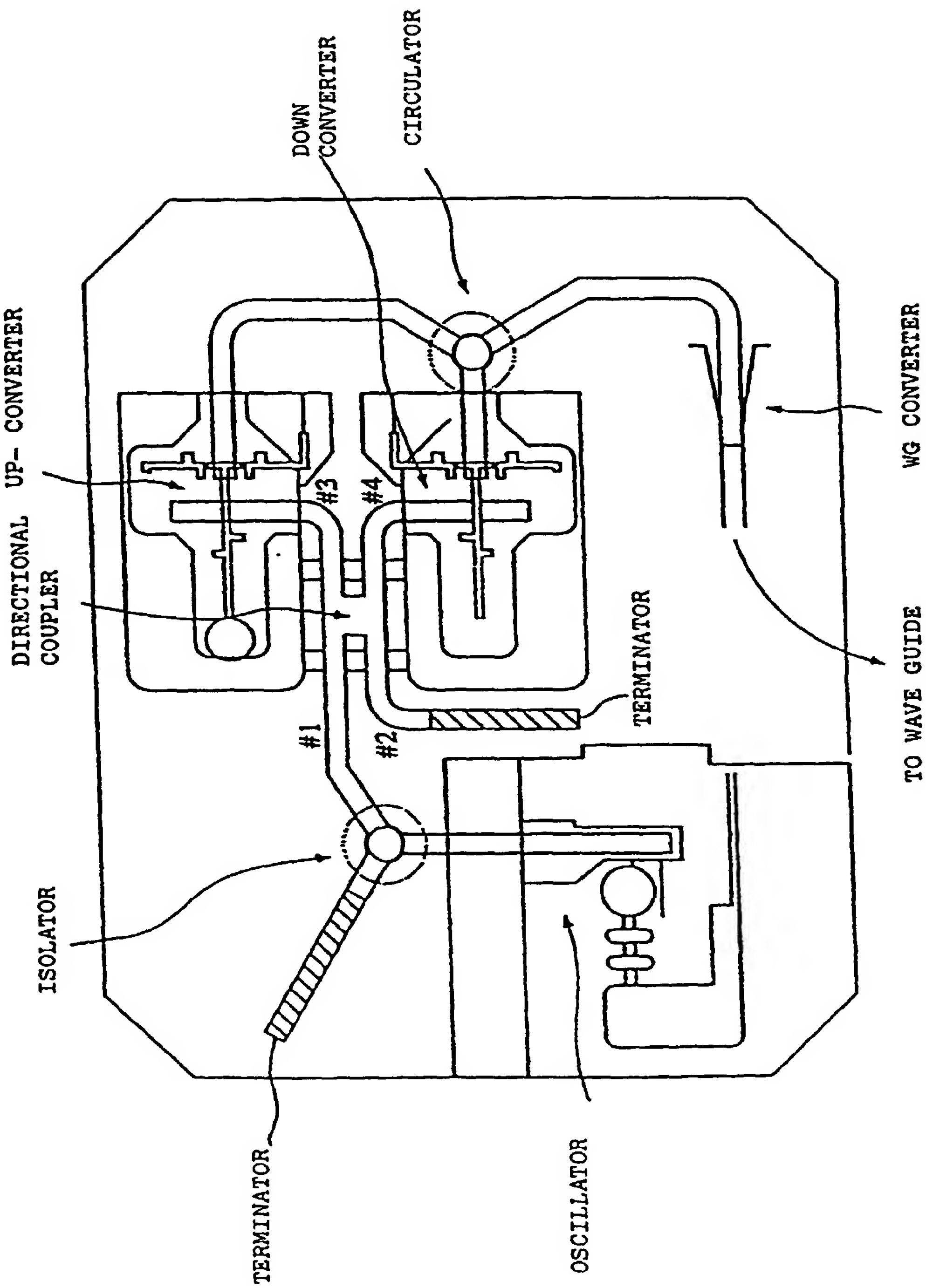

UP- CONVERTER
DIRECTIONAL COUPLER
DOWN CONVERTER
CIRCULATOR
#3
#4
#1
#2
TERMINATOR
WG CONVERTER
TO WAVE GUIDE
ISOLATOR
TERMINATOR
OSCILLATOR

FIG. 23

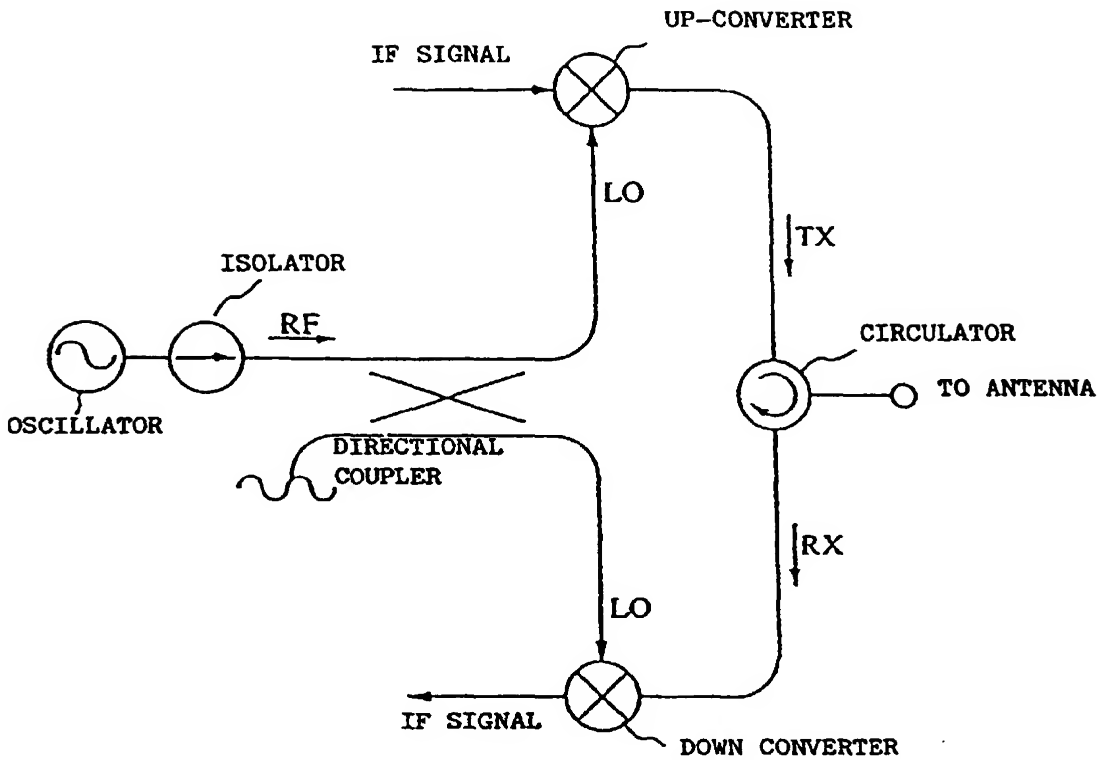

UP-CONVERTER
IF SIGNAL
LO
TX
ISOLATOR
RF
CIRCULATOR
TO ANTENNA
OSCILLATOR
DIRECTIONAL
COUPLER
RX
LO
IF SIGNAL
DOWN CONVERTER

FIG. 24

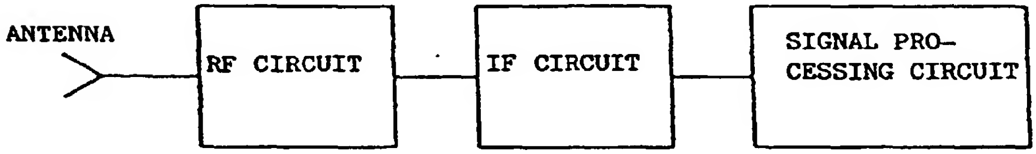

ANTENNA
RF CIRCUIT
IF CIRCUIT
SIGNAL PRO-
CESSING CIRCUIT

FIG. 25

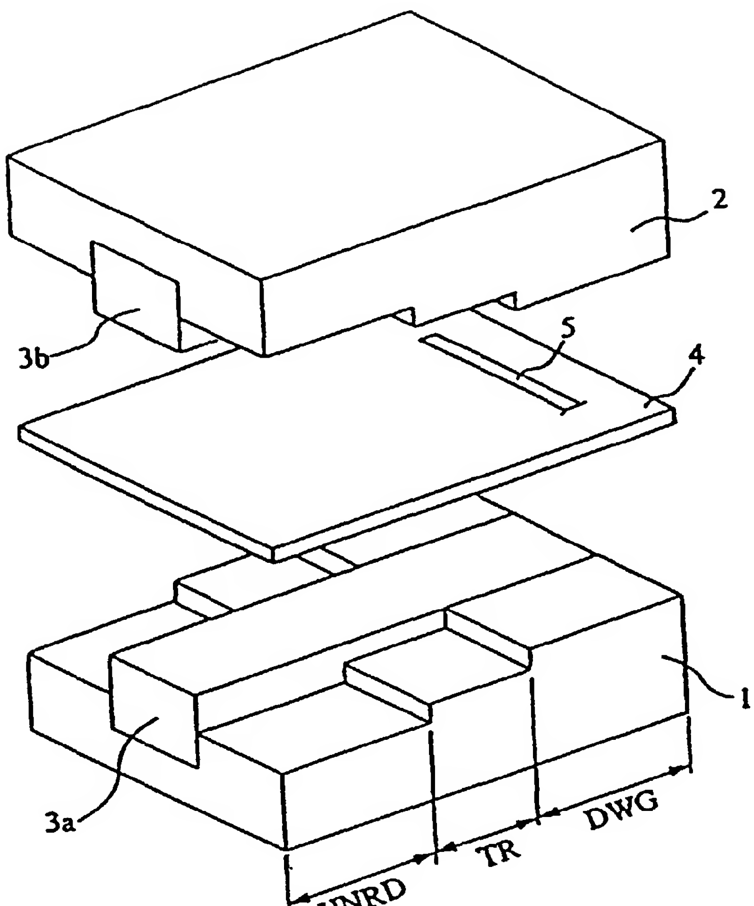


FIG. 26A

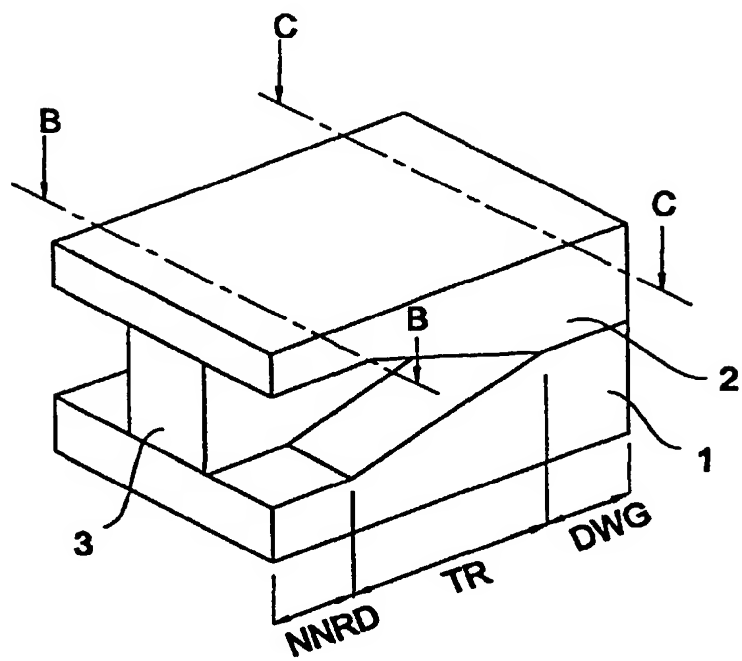


FIG. 26B

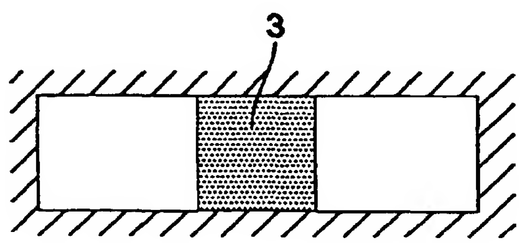
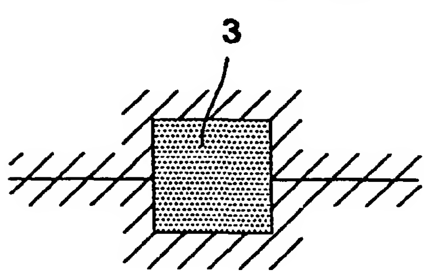


FIG. 26C



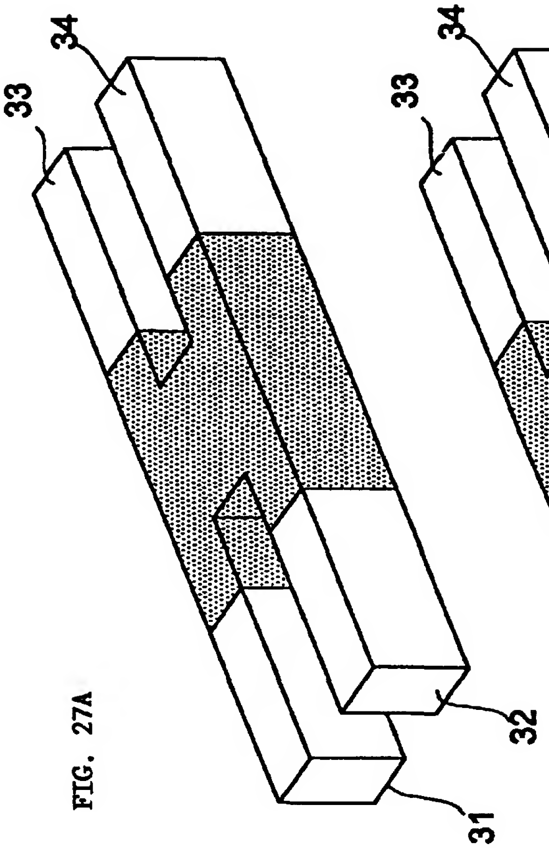


FIG. 27A

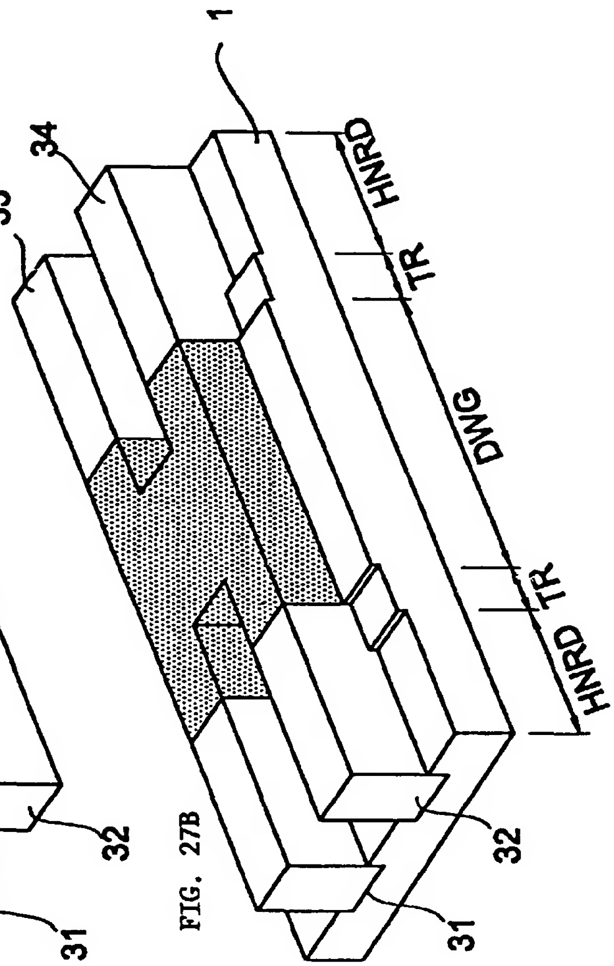


FIG. 27B